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NOTES ON SOIL AND EARTH TEMPERATURES

R W Gloyne

Introduction

Inquiries are frequently posed relating to various aspects of ground temperature; these include:

(i) the relationship between the customary 09h reading, the daily extremes and the 24 hr mean.

(ii) the effect of depth below surface on temperature.

(iii) the effect of ground cover (almost invariably the distinction between the bare soil on the one hand and on the other, a turf-cover - usually a cropped surface, but sometimes one of several inches long.

(iv) the effect of soil type and condition (mainly moisture status, but also aspects such as colour).

In respect of ground cover, it appears that the grass sward may range from a closely "shaved" bowling green type of surface (where the physics of heat transfer may well differ little from that of bare ground - setting aside the question of colour, i.e. "albedo") through to the 1 inch long uniform turf cover conforming to standard Meteorological Office practice, to a field-type sward of several inches. Investigations by meteorologists are normally carried out under one or other of the first two situations, whilst agronomists and others may frequently be properly concerned with a natural field sward. The effect of a dense, field-type, sward on the soil temperature at shallow depths is very marked, and under such a sward the diurnal fluctuations, even at only 10 cm under the soil surface, are likely to be small.

The Meteorological Office have adopted the following definitions:

Soil temperature: that under bare soil at depths of 20 cm (8 in) or less

Earth temperature: that at 30 cm (1 ft) or more under short turf

These are not universally adopted and the World Meteorological Organisation speaks of "soil" temperatures at 5, 10, 20, 50 and 100 cm under bare soil or under short turf and recommends parallel observations in both situations.

Some useful numerical data on soil and earth temperatures, in particular the deviation of the 0900 GMT reading from the 24 hr mean

There is a very extensive literature on all aspects of heat transfer and temperature in the soil. However in the UK, systematic observations which reach the pages of routine publications are usually restricted to data of the once daily observations of soil and earth temperature at 0900 GMT.

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In view of this limitation there may be some interest in the following information culled from sources immediately at hand to the writer. In the main the figures relate to the deviation of the mean 0900 GMT observation ($\overline{T}(09)$) from the mean for the complete 24 hour period ($\overline{T}(24)$), i.e. $\lceil \overline{T}(24) - \overline{T}(09) \rceil$: unless otherwise stated the estimates are derived from monthly mean values.

1. From unpublished papers in the Meteorological Office (Agr Memo No 25, 1959 by P Sarson and T H Applegate) (in °F).

$\lceil \overline{T}(24) - \overline{T}(09) \rceil$

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cockle Park (Morpeth)	4"	0.2	0.3	0.8	1.1	0.9	1.3	1.2	1.1	0.9	0.5	0.3	0.1
	8"	0.1	0.3	0.8	1.3	1.5	1.9	1.7	1.6	1.2	0.6	0.3	0.0
		(Soil - sandy loam overlying boulder clay)											
Houghall (Durham)	4"	0.3	0.6	1.2	1.5	1.8	2.0	1.9	1.7	1.5	1.1	0.5	0.0
	8"	0.1	0.1	0.4	0.6	0.9	1.1	0.9	0.9	0.7	0.3	0.1	0.1
		(Soil - sandy loam)											
Newton Rigg (N'land)	4"	0.2	0.3	0.8	1.0	1.2	1.2	1.1	1.0	0.7	0.4	0.2	0.0
	8"	0.1	0.3	0.6	1.0	1.3	1.3	1.2	0.9	0.6	0.4	0.2	0.1
		(Soil - medium loam)											

2. "Une annee d'enregistrement continu de la temp du sol" by M Hautenne (Inst Royal Met de Belg, Mem 1, 1952).

$\lceil \overline{T}(24) - \overline{T}(09) \rceil$ (in °F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.01 m (1 cm) Bare soil			0.5	-1.4	-2.5	-2.9	-3.6	-2.9	-1.1	0.5	1.6	0.4
0.01 m (1 cm) Short turf	0.7	1.1	1.4	2.3	2.0	2.2	2.7	2.2	2.2	1.8	1.3	0.4
0.10 m (≡ 4") Short turf	0.4	0.9	1.3	2.5	2.3	2.7	2.9	2.7	1.8	1.3	0.7	0.2
0.20 m (≡ 8") Short turf	0.2	0.5	0.7	1.6	1.8	2.0	2.3	1.6	1.3	0.7	0.4	0.2

The negative values very near the surface of freely exposed soil are in conformity with the much more marked differences reported in the summer months in Ref No 5 below and which were recorded at lower latitudes in a more sunny climate.

3. "Variation of soil temperature beneath turf - discussion of observations at Kew Observatory" by H L Wright (Mems Royal Met Soc IV (31).

$\lceil \overline{T}(24) - \overline{T}(09) \rceil$ (in °F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4" (turf)	0.7	0.9	1.8	2.4	3.0	2.5	1.7	1.9	1.6	1.2	0.7	0.2
8" (turf)	0.3	0.4	0.8	1.1	1.4	1.4	1.0	1.0	0.8	0.6	0.3	0.2

Observations made in 1927 - a rather dull rainy summer

4. "An experimental study of the propagation of heat in the soil" (in French) by L Elbe. La Meteorologie, Jul-Sep 1946.

$\lceil \bar{T}(24) - \bar{T}(09) \rceil$ (in °F)

	Winter	Spring	Summer	Autumn
10 cm (turf)	1.0	3.5	3.9	2.2

5. "Earth temperatures in different types of soil at Hokkaido" by R Yokuwa. Geophys Mag XIV No 1 Tokyo 1946 ppl-12.

$\lceil \bar{T}(24) - \bar{T}(09) \rceil$ (in °F)

Summer months only

	Volcanic Sand	Sand	Loam	Clay	Bog
0 cm	-15.8	-22.5	-15.8	-12.0	-11.0
5 cm	2.8	-1.0	1.5	1.4	3.9
10 cm	7.4	6.3	6.2	4.9	4.4
20 cm	3.3	4.2	2.6	2.1	0.0(+)

6. "The effect of weather changes on soil temperatures" by T B Franklin. Proc Roy Soc Edin Vol XL 1919-20.
Differences in mean temperature at 6" depth between two different soils (at Edinburgh).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sandy loam	-	-	-	-	0.8	1.2	1.2	0.3	0.0	-	-	-
Clay	0.9	0.8	0.7	0.2	-	-	-	-	0.0	0.7	1.0	1.2

NB This paper is very informative regarding certain aspects of temperature and heat transfer at a site in the Edinburgh area.

7. "Examination of some observations of soil temperature (at Starcross, Devon, 1948/49)" by R W Gloyne, J Brit Grassland Soc 5(2), June 1950, ppl157-177.

$\lceil \bar{T}(24) - \bar{T}(09) \rceil$

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4" (bare soil)	1.3	2.1	2.6	2.4	2.3	2.6	3.1	3.4	3.1	2.4	1.4	1.1
8" (bare soil)	0.6	1.1	1.6	2.0	2.4	2.9	3.0	2.8	2.3	1.5	0.7	0.5

(Soil - deep sandy loam developed from Permian Breccia)

8. Unpublished data from experiments at Long Ashton Research Station (1949). Rough estimates from graphs.
Values of $\lceil \bar{T}(24) - \bar{T}(09) \rceil$ on days with clearly marked diurnal variation, i.e. almost invariably these will be dry days with much bright sunshine.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4" (bare soil)	2.5	3.2	3.8	4.2	5.0	5.5	5.3	[4.1]	[2.0]	[1.5]	1.5	2.0
8" (bare soil)	1.0	1.5	2.2	2.8	3.5	4.1	4.5	4.5	3.5	2.5	0.5	0.8

[ ] = doubtful

Some conclusions

(1) In lower latitudes (say 40°N) areas enjoying a high level of solar radiation, the diurnal variation of soil temperature at shallow depths (say 5 to 20 cm) under a bare or closely cropped grass surface is such that the 24 hour (i.e.

the daily) mean value exceeds that at 0900 GMT by 4°–6°F.

Nearer or at the surface, under high radiation and especially in the early summer when mean temperature is rising, the 0900 GMT temperature can exceed the 24 hour mean by amounts up to 20°F (Ref 5).

(2) The same tendency is evident in the data from the cloudier climate of the Low Countries, France and Southern England (Ref 2), although the absolute values are typically one half or less than those referred to in (1) above.

In these areas, at depths of say 5–10 cm the mean monthly 0900 GMT temperature is typically from 2°–3°F lower than the 24-hour mean (Refs 2, 3, 7) at 10–20 cm the differential is less (say 1 to 2°F).

However in dry sunny weather, the differences are greater – say double those of the mean monthly value (Ref 8).

(3) In Northern Britain the differences on a monthly mean basis are less than those quoted above in (2) – see Ref 1, although it would be prudent to assume that in dry sunny weather and in certain soils (mainly "light" sandy soils) differences approaching those experienced in Southern England (say, 3° to 5°F at 10 cm depth and 2° to 4°F at 20 cm depth).

However it would seem likely that, averaged over a month, we can suggest the following value of $\left[\bar{T}(24) - \bar{T}(09) \right]$ for Scotland:

	Winter	Spring & Autumn	Summer
At 10 cm depth	0.0 to o.5°F	0.5 to 1.5°F	1.5 to 2.5°F
At 20 cm depth	0.0 to 0.5°F	0.5 to 1.0°F	1.0 to 2.0°F

(4) Soil type (especially the contrast between the situation in sand and in clay – in the limit waterlogged bog) in regions having a high level of solar radiation can exert a measurable influence upon soil temperature, especially in the uppermost layers. Temperature in sandy soil tends to be high by day, but may be the same, or rather lower by night than in loams and clays. Variations in moisture content can significantly affect soil temperature and can override soil-type differences except for the extreme soil categories. Ref 6 indicates the order of magnitude of the mean difference due to soil type (the differences are obviously also linked to the moisutre content of the soil).